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Training Perceptual Skill by Orienting Visual Attention

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A major element in expert sports performance, particularly racket-and-ball games, is excellent anticipatory skill. A prestudy combined the temporal and spatial occlusion paradigms to ascertain which key stimuli badminton players use for anticipating the direction of overhead shots. The main study then evaluated a program for training anticipatory skills; 200 video clips were employed to orient attention toward these key stimuli. Participants were 63 badminton novices, 20 national league players, and 21 local league players. A transparent red patch (exogenous orienting) was used to orient attention toward the trunk up to 160 ms before racket-shuttle contact; the arm, from 160 ms to 80 ms before contact; and the racket, from 80 ms before to actual contact. Results showed that badminton novices who trained with this program significantly improved their anticipatory skill between post- and retention test compared with controls. Whereas local league players improved from pre- to posttest, training had no effect on expert national league players. It is concluded that using red transparent patches to highlight the most informative cues in perceptual training programs is a promising way to improve anticipatory skill.

Key Words: anticipation, training, badminton, temporal occlusion

Many sport situations call for a differentiated perception of an opponent's motor behavior. Because the high speed of play frequently leaves very little time for preparing one's own motor responses, it is necessary to deduce which direction the opponent may take from an early phase of movement execution (Abernethy, 1993). Various *temporal occlusion* experiments have confirmed that experts can make earlier and more precise predictions on the direction in which an opponent will act. A typical experiment in this field presents experts and novices with video sequences of a specific type of sport that display the opponent from the perspective of the receiver. These videos stop at a certain point in time (e.g., when the racket hits the ball), and participants are asked to predict which direction the action will take.

Williams and Burwitz (1993), for example, applied this temporal occlusion technique to soccer. They asked 30 expert and 30 novice soccer goalkeepers to predict the shot direction (one of the four corners of the goal) of 40 temporally occluded penalty kicks. The goalkeepers watched short video sequences on a screen displaying kick movements under four temporal conditions: (a) up to 120 ms before

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ball contact, (b) up to 40 ms before ball contact, (c) up to ball contact, and (d) up to 40 ms after ball contact. Results showed that experienced goalkeepers produced much better predictions than novices, particularly under the 120-ms condition.

Further examples using this approach can be found in tennis (e.g., Farrow, Abernethy, & Jackson, 2005; Goulet, Bard, & Fleury, 1989; Rowe & McKenna, 2001; Williams, Ward, Knowles, & Smeeton, 2002), badminton (Abernethy & Russell, 1987a, 1987b; Hagemann & Strauss, 2006), soccer (Williams & Davids, 1998), cricket (Houlston & Lowes, 1993), squash (Abernethy, 1990), and karate (Mori, Ohtani, & Imanaka, 2002).

The usual way to study which visual information is taken from a movement pattern is to analyze eye movements (for an overview, see Cauraugh & Janelle, 2002). The information processing paradigm assumes that knowledge of experts' eye movements (visual fixation points) can be used to model their information pick-up. However, even full knowledge of gaze behavior does not provide exhaustive information on which stimuli are actually perceived, because experts may well use not just foveal information but may also respond to peripheral stimuli when controlling their behavior. Because the retinal periphery is highly adapted for perceiving information on movements (Milner & Goodale, 1995), information input may also be influenced by orienting attention toward peripheral stimuli (e.g., Posner, 1980).

Another approach in studying information pick-up is the *spatial or event occlusion* technique, which is usually combined with the temporal occlusion paradigm. To identify the most informative visual cues in the display, specific cue sources are occluded during the video sequence, for example by a black patch. The idea is that if a visual cue is important, its occlusion will lead to a decline in performance compared with a control condition.

Abernethy and Russell (1987b), for example, studied how precisely the landing position of a badminton shuttle could be determined after viewing a variety of locally masked shots. They presented 32 play sequences in which either (a) the arm and the racket, (b) only the racket, (c) the head, (d) the lower body, or (e) background areas were masked. A comparison of skilled national badminton players with novices showed that experts' predictions were better under all conditions except when the arm and racket were occluded. By partialing out prediction performance without masking, Abernethy and Russell were able to ascertain the major information-containing regions for different levels of expertise. For example, novices drew most of the essential information for their predictions from the motion of the racket. Skilled badminton players particularly use the arm movement and the motion of the racket, but they also draw in part on the posture and movement of the head and lower body. Abernethy and Russell (1987b) then went on to study the eye movements of experts and novices but were unable to find any major differences in visual search strategies.

Training Perceptual Skill in Sport

The exceptional perceptual skills of skilled athletes in different types of sport have served as a starting point for numerous experiments seeking an empirical basis for training programs (Farrow & Abernethy, 2002; Farrow, Chivers, Hardingham, & Sachse, 1998; Williams, Ward, & Chapman, 2003; Williams et al., 2002). Because of the importance of perceptual processes for skilled performance, training programs have been marketed commercially which claim to improve general abilities such as depth perception, visual acuity, and peripheral vision (e.g., "Sports Vision" from Revien

& Gabor, 1981; "Eyerobics" from Revien, 1987; or "SportsVision" from Wilson & Falkel, 2004). However, the benefits of such programs are doubtful and lack empirical confirmation. Indeed, research has even shown that experts do not have better general visual perception skills than novices (Abernethy, Neal, & Koning, 1994; Abernethy & Wood, 2001; Helsen & Starkes, 1999; Ward, Williams, & Loran, 2000).

In contrast to such general perceptual training programs, there is broad empirical evidence that visual information processing can be trained in specific sports (Farrow & Abernethy, 2002; Farrow et al., 1998; Williams et al., 2002; 2003). As pointed out above, experts are characterized by being better at anticipating the actions or reactions of their opponent. As a result, sport-specific training studies attempt to train the perception of specific movement patterns (e.g., slice serves in tennis) and relate these patterns to the outcome of the action (e.g., where the ball lands).

Perceptual training programs have been developed and applied frequently in racket-and-ball games such as tennis (Abernethy, Wann, & Parks, 1998; Williams & Grant, 1999; Williams & Ward, 2003; Williams, Ward, & Smeeton, 2004). For example, Scott, Scott, and Howe (1998) worked on an anticipation training program for intermediate-level tennis players. Over several sessions, three male and three female participants watched 20 video clips projected at five different speeds. The opponent's serve, which was visible in the clips, was always broken off at ball contact. The task was to predict where the ball would actually land. This intervention or training phase was supplemented with test phases on the tennis court. After the total training program was completed, the video-simulated training was found to have had positive effects on anticipatory skill and also to have exerted a positive influence on returning serves on the real tennis court.

Instruction

In recent years many studies have examined the possible influence of different instructions (e.g., Farrow & Abernethy, 2002; for an overview see Jackson & Farrow, 2005; Smeeton, Williams, Hodges, & Ward, 2005; Williams et al., 2002). These have been searching for a superior instruction method that would make athletes aware of which characteristics of a movement are relevant in a specific type of sport (for motor skill acquisition, see Janelle, Champenoy, Coombes, & Mousseau, 2003).

Skilled sport performance is possible only if attention is directed toward task-relevant features (Abernethy, 2001; Janelle, Duley, & Coombes, 2004). Orienting attention toward a certain region or a certain object also makes it possible to detect a stimulus more quickly and identify it more precisely (Yantis, 1998). However, sport situations are characterized by a large amount of complex visual information, making it necessary to detect and select the most informative cues. Particularly in racket-and-ball games, in which the receiver already has to react to the opponent's shot while it is being prepared, focusing attention on relevant body regions has proved to be crucial for skilled performance (Abernethy, 2001).

Basically the different instruction methods in visual perception training can be distinguished according to how explicitly the relevant movement features in the type of sport should be communicated. Farrow and Abernethy (2002), for example, studied the impact of explicit and implicit instructions on the prediction of tennis serves. An explicit-learning group completed 12 training sessions with 50 video clips and was informed about relationships between certain movement features (e.g., ball toss, angle of racquet head, and shoulder rotation) and the direction of the serve. An implicit-learning group watched the same video clips and was told to estimate the speed of the serve. Compared with the explicit group as well as control and placebo groups (receiving no video training and watching clips from professional tennis matches, respectively), those in the implicit-learning group were able to increase their predictive skill significantly in the posttest. However, this improvement could not be replicated 32 days later in a retention test.

Williams et al. (2002) used performance on predicting tennis serves to evaluate the effectiveness of two different instruction methods. An explicitly instructed group received information on the major movement features and how they relate to the direction of the serve. Another group, guided discovery, had these features pointed out to them but had to work out the connection between body posture and direction of the serve themselves. No differences in effectiveness could be ascertained between the two groups. However, compared with control and placebo groups, the two treatment groups managed to improve their reaction speeds in both a laboratory test and an anticipatory test on the tennis court.

The effects of both different instructions and implicit learning methods show that observation strategies can be applied successfully in perceptual training. However, it is still not known which instruction method orients attention most effectively. Magill (1998) has also discussed the effectiveness of different instruction methods on learning regular sequences of movement in sports. He noted that specifically in the perceptual learning of regular movement patterns in sports, direct cues that emphasize certain movement features can lead to worse performance than indirect cues (implicit learning or guided discovery). In addition, perceptual performance can break down under stress conditions (Smeeton et al., 2005). Magill (1998) therefore proposed that attention should be oriented toward the information-rich areas that contain the most important motion features.

This leads to the issue of the breadth of attentional focus that is so crucial for the processing of visual information, the *zoom-lens* metaphor: the narrower the focus, the more efficient the processing of information per surface unit (Castiello & Umilta, 1990; Eriksen & St. James, 1986; Eriksen & Yeh, 1985). This breadth varies for different types of sport (Nougier, Stein, & Bonnel, 1991). For many with an invariant visual setting, such as archery, a narrow focus is advantageous. However, in a continuously changing situation (an open-skill sport), a relatively broad focus oriented toward the center of the relevant information is preferable (Ripoll, 1988). An appropriate breadth of the focus of attention is something that players develop with increasing experience, making it one of the features of expertise in a specific sport (Nougier, Stein, & Bonnel, 1991). If possible, this should also be taken into account when training perceptual skills.

Orienting Visual Attention

Alongside the explicit and implicit instruction methods presented above, there is also one further method that, as far as we know, has yet to be applied in training studies on perceptual learning in sport. *Attention cues* can be used in visual displays to direct participants' attention toward certain features (Posner, 1980). This makes it possible to manipulate not only the areas in the display but also the breadth of the focus of attention (Castiello & Umilta, 1990; Greenwood & Parasuraman, 2004). Grant and Spivey (2003), for example, highlighted single features in a static visual picture to test whether this would help participants find the right answer to a problem-solving task (Dunker's radiation problem). They used pulsing to highlight the relevant features; that is, the breadth of a feature (in this case, a circle) fluctuated by one pixel three times a second. Grant and Spivey concluded that manipulating attention through "a subtle increase in perceptual salience of a critical diagram component increased the frequency of correct solutions" (p. 465).

Two control mechanisms for orienting attention can explain the impact of highlighting visual stimuli in a display. Both Posner (1980) and Jonides (1981) have distinguished between an endogenous or voluntary orienting (top-down or goal-directed) and an exogenous or reflexive orienting (bottom-up or stimulus-driven; see also Yantis & Jonides, 1990). The exogenous orientation mechanism is triggered either when an unexpected object appears in the visual field or when there is a strong change in luminance. The endogenous control mechanism is used to orient attention intentionally toward a specific object or spatial event through the interpretation of visual information. One distinct advantage of the exogenous control mechanism is that the focus of attention can be influenced automatically without drawing on cognitive resources (Yantis, 1998).

The present study tested whether the advantages of manipulating the orientation of attention through visual cues in a display would also apply to visual perception training. A training program was developed that should avoid the three main errors in orienting or focusing attention described by Abernethy (2001, p. 71): (a) focusing attention on more than the relevant information ("having the searchlight too broad"); (b) focusing attention on irrelevant information ("having the searchlight pointed on the wrong direction"); and (c) not being able to focus attention quickly enough on all relevant information in succession ("having the searchlight beam too narrow or being unable to move the searchlight rapidly enough from one spot to the next").

The attention-orienting method presented below is designed explicitly to counteract these errors. It views the adaptation of attention orienting to fit the specific type of sport as a skill representing one of the parameters of skilled sport performance (Janelle et al., 2004).

The Research Question

In the present study, players had to learn both the location and breadth of the focus of attention through watching video clips to which a transparent red patch had been added. The transparency of this patch was varied in order to ensure that the underlying video sequence would still be easy to see. Its location corresponded to the focus of attention ascertained in experts.

We tested this technique of orienting attention exogenously in a learning experiment with badminton novices (main study). This is an appropriate field for a learning experiment aimed at improving anticipatory skill, because the high speed of shuttles, up to 174 mph, calls for the development of attention strategies with which to already identify the key stimuli in the execution of the movement leading up to the shot. Furthermore, it is possible to draw on comprehensive prior research on this sport (Abernethy & Russell, 1987a, 1987b).

A prestudy was carried out in order to determine where attention needed to be focused, and thereby the locations with the most important action-guiding information. Because this prestudy has been reported elsewhere (Hagemann & Strauss, 2006), we shall only summarize the main methods and findings to provide enough information for understanding the present main study (the learning experiment).

Prestudy: Determining the Spatiotemporal Course of Visual Information Pick-Up

Previous experiments using the event occlusion technique (Abernethy & Russell, 1987b; Williams & Davids, 1998) did not consider that when skilled athletes make predictions, they can use different visual cues at the beginning of the shot preparation compared with those at the end. The prestudy analyzed the spatiotemporal course of visual information pick-up to ascertain which visual cues are used at which point in time for predicting the shot direction of badminton players. It applied a combination of the temporal occlusion and spatial occlusion techniques (Abernethy & Russell, 1987a, 1987b). Various video sequences were produced in which one region, such as the trunk, was masked with an opaque patch for a fixed time interval (e.g., up to 80 ms before racket-shuttle contact).

If an important visual cue is occluded during that time interval, this should result in a decline in anticipatory performance. By using the progressive temporal occlusion technique (4 levels, from 160 ms before racket-shuttle contact until 80 ms after contact), we can infer which visual cue is important at which time. Performance differences were ascertained for seven regions (trunk, legs, shoulders, head, arm, racket, background) at four different times. The prestudy used the same regions as Abernethy and Russell (1987a, 1987b) but added two further body areas, the legs and shoulders (Hatzl, 2000), to determine information pick-up in a somewhat more differentiated way.

Badminton overhead shots were recorded with a Panasonic DCR-TRV950E digital video camera and digitalized in mpg-1 format. The videos were integrated into a specially written software program called BAT 1.0 (Badminton Anticipatory Test). The program presents the video clip with a resolution of 720 × 576 pixels in the upper left corner of a display (see Figure 1).

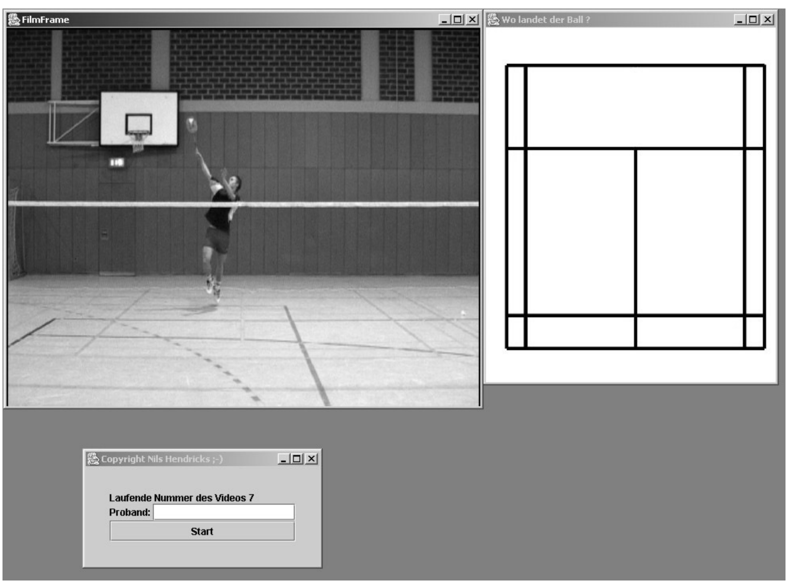

Figure 1 — BAT 1.0 screen for badminton shots.

Participants used a mouse click to mark where they expected the shuttle would land on the receiver's half of a badminton court displayed on the right side of the screen. Although they did not have to perform the mouse click under time pressure, they were encouraged to reach an immediate decision. A total of 112 videoclips[1] (56 with spatial occlusion) of badminton overhead shots performed by national league players were displayed from the perspective of the receiving player.

For the anticipation test, we edited the length of the videos (temporal occlusion) so that 14 clips showed badminton shots up until 160 ms prior to racket-shuttle contact; 14 clips up to 80 ms before contact; 14 clips up to contact; and 14 clips until 80 ms after contact. The 14 video clips for each stage in the temporal occlusion condition were edited further so that one of the seven regions was hidden by an opaque patch (spatial occlusion) in 2 out of each block of 14 videos.

The results presented here report prediction performance of 20 first and second national league badminton players and 23 local league players. The national league players had a mean age of 23.60 years (*SD* = 3.05) and had been playing in the national league for an average of 4.50 years (*SD* = 3.09). The local league players had a mean age of 26.30 years (*SD* = 7.84) and had been playing in local leagues for an average of 3.39 years (*SD* = 3.75).

Figure 2 presents differences in prediction performance as a function of the spatially occluded versus unmasked video clips for each temporal occlusion condition (shoulder, head, and background regions have been dropped for ease of presentation). A positive value represents a drop in prediction performance when the visual cues are hidden in the video clips. Hence, the figure shows which visual cues at which points in time provide important information for predicting the direction of the shot. The video clips up to 160 ms before racket-shuttle contact revealed a broad range of responses, indicating that it was very difficult to derive a reliable estimate of the landing position from such short sequences. Using multiple *t*-tests[2],

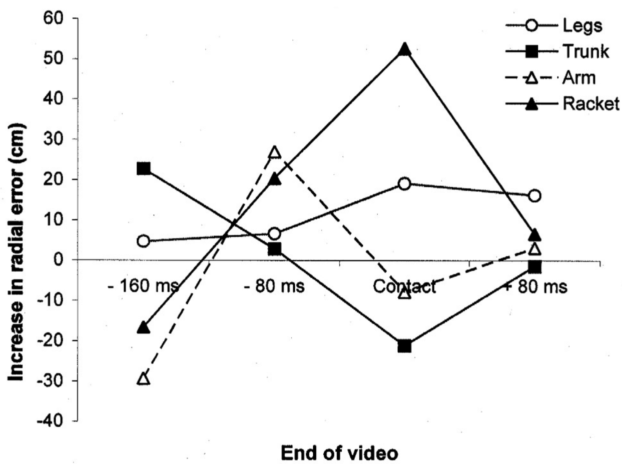

Figure 2 — Increase in radial prediction error for different masked body areas as a function of length of video clip. The increase is calculated from the difference between the prediction performance on the video clip without masked areas and the video with masked areas.

Hagemann and Strauss (2006) reported a significant drop in radial prediction performance when the trunk was masked, $t(42) = 1.82$, $p < .05$, one-tailed, $d = .30$. This suggests that movement of the body (e.g., rotation around the vertical body axis) at the beginning of the shot provides information on its direction. From 160 ms to 80 ms before racket-shuttle contact, the arm movement contained the most important information for predicting the landing position in one's own court, $t(42) = 1.45$, $p = .08$, one-tailed, $d = .20$.

For the video clips up to contact, masking the racket produced the strongest deviation of 52.69 cm in the prediction of the landing position, $t(42) = 3.57$, $p < .01$, one-tailed, $d = .80$. In the videos that also depicted part of the flight of the shuttle (up until 80 ms after racket-shuttle contact), masking single regions of the body did not elicit such a strong drop. Masking the leg region made the strongest contribution here to declining anticipatory performance, $t(42) = 2.06$, $p = .02$, one-tailed, $d = .29$. Probably the lack of single videotaped elements in the long video clips was compensated for by interpolating neighboring picture information (perceptual flexibility). In sum, it can be concluded from these findings that, initially, proximal visual cues (up to 160 ms before rattle-shuttle contact) are used to predict the direction of badminton overhead shots; information on distal motions (arm and racket) is only used later.

Main Study: Training Anticipatory Skill by Orienting Attention

The main study examined the effect of highlighting those regions from which badminton players in the prestudy had extracted the most important information for predicting the direction of the shot. As described above, attention was oriented toward these areas by adding a transparent red patch to the training video clips. We anticipated that this attention orienting would enable badminton novices to learn to recognize regularities in the movement patterns in these body regions.

The variable "training program" was presented on three levels. In one group, attention was drawn to the regions ascertained in the prestudy through a transparent red patch (attention-oriented group, $n = 23$). A second group watched the same video sequences without the regions being emphasized by a transparent red patch (video-alone group, $n = 20$). Finally, a control group ($n = 20$) did not complete any training program. All three groups completed the Badminton Anticipatory Test (BAT 1.0) with 84 video clips before, immediately after, and approximately 7 days after the training program ($M = 6.57$ days, $SD = 2.65$). All 63 badminton novices were sport students with an average age of 25.8 years ($SD = 3.4$, range = 18–35 yrs).

To assess possible effects of the training program on experienced badminton players as well, we formed two further groups: national league players and local league players. Because we anticipated no learning effects in these groups, particularly in the national league players, we dropped the retention condition and did not use a control group. The 20 experts were players in the first or second national badminton league at the time of the study. Their mean age was 24.2 years ($SD = 6.5$, range = 17–39 yrs), and they had been playing in the national league for an average of 6.31 years ($SD = 6.57$). Those in the second group of 21 participants were active members of local teams. Their mean age was 25.5 years ($SD = 6.7$, range = 17–40 yrs). At the time of the study they had been playing in local leagues for an average of 3.80 years ($SD = 4.28$).

Table 1 Research Design and Number of Participants per Training Type and Level of Expertise

Group	Pretest	Training	Posttest	Retention test
Novices (n = 63)				
	23	Attention	23	23
	20	Video	20	20
	20	No training	20	20
National league players (n = 20)				
	10	Attention	10	–
	10	Video	10	–
Local league players (n = 21)				
	10	Attention	10	–
	11	Video	11	–

Ten national and 10 local league players were assigned randomly to the attention-oriented group; the remaining 10 and 11 players, respectively, were assigned to the video-alone group. Table 1 reports the distribution across groups for all 104 participants. None of them had taken part in the prestudy, and all were volunteers who received no payment for completing the experiment.

The Training Program

Both forms of the training program contained the same 200 basic sequences presented in random order. The program was administered as one single training session lasting about 45 min. Participants saw overhead shots of three national league badminton players from the perspective of the receiver. Each shot was presented twice. The first trial stopped at the time of racket-shuttle contact. Then the participant had to use a mouse click to enter the estimated landing position of the shuttle in his own half of the badminton court depicted on the right side of the screen. As soon as the program recorded the mouse click, the estimated position was displayed with a red point and the correct position with a green point. Then the program started the second video clip, showing the same shot right through until the shuttle landed in the receiver's court. The participant then used a mouse click to begin the next video sequence.

The training program for the attention-oriented group used a transparent red patch to highlight the trunk up to 160 ms before racket-shuttle contact, the arm region from 160 ms to 80 ms, and the racket region from 80 ms to shuttle contact. The breadth of the focus of attention corresponded to the size of the patch in the prestudy. The patch highlighted the relevant body regions to orient attention toward them. The idea was that novices would learn the location at which they should orient attention through the change in the highlighted regions. However, participants in this attention-centered group were not given any explanation for these transparent red patches.

There was a 5-min break between each section of the experiment. Depending on individual decision-making and clicking speed, the experiment took about

70 minutes to complete. The control group, which did not complete any training program, had an unstructured 45-min break between pretest and posttest. After the study all participants completed a short questionnaire on their sports background. All sessions were carried out in a quiet environment so that participants could work with as little interruption as possible.

Results

This section begins with the results of the training intervention for novices before focusing on the differences between the video and attention groups on all three dependent variables (radial, lateral, and depth error). Because national league and local league players completed only the pretest and posttest, their results are presented separately.

The 3 × 3 (Group × Measuring point) mixed randomized-repeated ANOVA revealed a significant interaction between novice group (attention, video alone, control) and measurement time (pre-, post-, retention test), $F(4, 120) = 5.40$, $p < .01$, $\eta_p^2 = .15$. A comparison of the course of the novices' predictions in the three groups over the three measurement times showed that both video-based training groups improved their anticipatory skills compared with controls (see Figure 3). This was also confirmed by the separately computed significant main effects on the repeated-measures variable (block) for the two training groups, $F(2, 82) = 11.73$, $p < .01$, $\eta_p^2 = .22$. Looking only at the two training groups, the visual attention group showed the strongest posttest retention test improvement (see Figure 3). This was confirmed by testing the contrast between the two last measurement points for the interaction between training group and block, $F(1, 41) = 5.21$, $p < .05$, $\eta_p^2 = .11$.

Figure 4 presents changes in lateral and depth deviations as a function of training group. The control group showed no change across time in either depth or lateral predictions. Therefore, for ease of presentation it is not depicted here. The

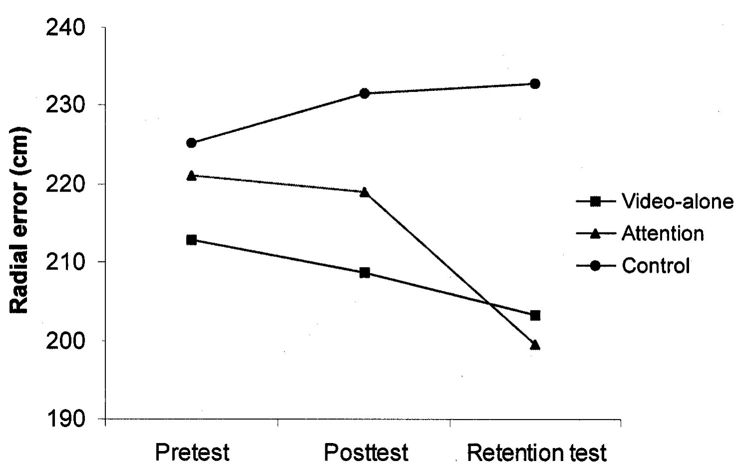

Figure 3 — Change in prediction skills in the three groups over pre-, post-, and retention tests.

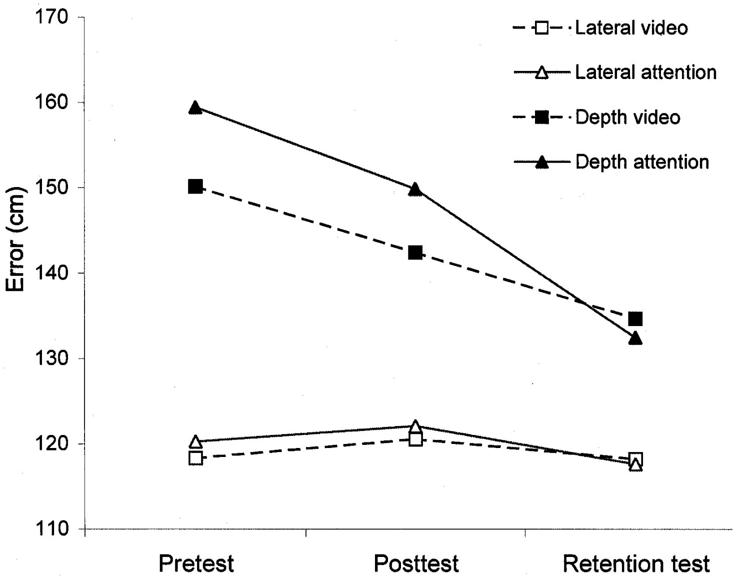

Figure 4 — Lateral and depth deviation over the pre-, post-, and retention tests for the attention-oriented and video-alone groups.

strongest differences were found between depth and lateral anticipatory skill independent of time point, $F(1, 41) = 65.92, p < .01, \eta_p^2 = .62$. Figure 4 also reveals a relationship between changes in lateral prediction performance and training program. Improvements in radial prediction performance were due mainly to improvements in estimating the depth direction (length of shot), $F(2, 82) = 14.43, p < .01, \eta_p^2 = .26$, with the attention-oriented training group showing stronger improvements in depth prediction performance than the video-alone training group (25.94 cm vs. 15.44 cm). The interaction between the two training groups from pretest to retention test just failed to attain statistical significance, $F(1, 41) = 3.88, p = .06, \eta_p^2 = .09$.

The participants from the national and local leagues completed only the pretest and posttest. Therefore only these first two measurement times could be used to determine the impact of league level and training program on prediction skill. There was a significant Time × League level interaction, indicating a differential impact of the video training as a function of league level, $F(2, 78) = 3.61, p < .05, \eta_p^2 = .09$. Local league players showed the greatest improvements in performance regardless of the type of video training.

The national league group revealed no significant time effect between pretest (185.08 cm, $SD = 21.98$) and posttest (181.78, $SD = 31.38$), and no effect for the training program (improvement of 4.87 cm in the video-alone group vs. 1.74 cm in the attention-oriented group). This was not the case for the local league players: this group improved their mean radial prediction from 216.74 cm ($SD = 28.36$) to 196.31 cm ($SD = 25.65$). This improvement was highly significant, $F(1, 19) = 14.99, p < .01, \eta_p^2 = .44$. However, no interaction effect was found for the training program; that is, both training measures were equally effective.

General Discussion

This study confirms that a video-based and an attention-oriented perceptual training have clear effects on novice badminton players. In all, both types of training have a very strong impact on estimating the direction of the shot. The high effect size of $\eta_p^2 = .22$ can be taken to confirm the practical value of giving video training to novice badminton players (Cohen, 1988, p. 287, proposed a $\eta^2 = .1379$ as a large effect). The lack of a clear training effect immediately after the training phase (posttest) may have been due to the structure of the training program. Because both national and local league players also took part, the training as a whole was organized as a single session so that these players could be tested on location. Together with the pre- and posttests, this means that the total program lasted about 70 min (excluding the retention test). Participants may well have found it hard to concentrate for such a long time, so that the effects of the training intervention could not be ascertained until the retention test. Predictive performance might have been even better one day or several hours after the posttest (due to regeneration).

Badminton novices find it very hard to estimate which direction a shuttle will take. Frequently they only start their return when they can tell where the shuttle is heading from its flight. The major improvements in their performance can be traced back to the recognition of regularities in the patterns of shots. A shot movement is linked to the potential position at which the shuttle will land in one's own court.

The prestudy determined the spatiotemporal course of visual information pick-up of badminton players, and showed which body regions at which time provide important cues regarding the shot's direction. This prestudy applied both the *temporal occlusion* conditions and the regions used in the *event occlusion* condition by Abernethy and Russell (1987a, 1987b), plus two further regions (legs and shoulders) to gain a more differentiated picture. Nonetheless, this procedure is still only an approximation of the visual cues actually used for prediction. The areas and their *breadth* were selected a priori and have not been ascertained or manipulated experimentally (Castiello & Umilta, 1990). Moreover, cues as to the direction of the shot may well come from the movement of several parts of the body in relation to each other or even the movement of the body as a whole. To examine this possibility, it would be necessary to link together various neighboring regions and analyze the effect of their occlusion. Abernethy and Russell (1987a, 1987b) had already applied this approach with the region "arm plus racket" (also see Müller, Abernethy, Farrow, Guy, & Barras, 2005). The new event occlusion technique might be useful here because of the possibility of using digital video processing to replace certain body regions by the background (Poulter, Jackson, Wann, & Berry, 2005). Regions can then be deleted much more precisely, and this would also help to overcome the problem of participants being distracted by black patches in video clips.

How far the information input ascertained by combining the temporal and spatial occlusion techniques relates to the eye movements of experts will need to be studied in further experiments combining all three techniques. These could determine, among other things, whether the relevant movement information is extracted at the fovea or in the periphery. It would be advantageous to use an even higher spatiotemporal resolution of the occlusion techniques in such comparisons. This could then be applied to different types of sport in order to ascertain the extent to which different types of experts use similar types of information input.

By orienting attention exogenously to the regions determined in the prestudy, the training attempts to highlight the movement pattern that is manifested in the motions of the body segments and thereby promote rapid learning. Highlighting the trunk (up to 160 ms before racket-shuttle contact), arm (from 160 to 80 ms before), and racket (from 80 ms to contact) results in a more positive course of learning than not highlighting them. As in other fields of research (Grant & Spivey, 2003), the present study also reveals the benefits of orienting attention with cues in a visual display. Focusing on the relevant body parts helps novices to recognize movement patterns more quickly.

Even though the transparent red patches are designed to address the exogenous orientation mechanism of attention (Posner, 1980; Yantis, 1998), we cannot rule out the possibility that they also address orientation endogenously. This applies particularly when highlighting the trunk region, because the partial visibility of the patch as well as the duration of presentation could lead to a specific (endogenous) focus (top-down or goal-directed; see Yantis & Jonides, 1990). Later in the shot sequence (from 160 ms before to racket-shuttle contact) it is hardly possible to react to the cue endogenously, because the transparent cues are visible for only 80 ms and also they switch too rapidly from arm to racket. Even if, as suggested above, one can try to gain the advantage of an automatic focus of attention with the exogenous mechanism, this cannot be guaranteed with the technique chosen here. This in turn is in line with Yantis' (1998) assumption that these two mechanisms are, in any case, not completely independent from each other.

An examination of the individual error components (radial, lateral, and depth error) reveals some interesting findings. It is highly notable that the improvements in the video-based training groups are particularly due to better estimation of the length of the shot (depth error). Good length estimates are a major characteristic of experts (Hagemann & Strauss, 2006). Hence, this feature can be addressed with a video-based training program. This finding confirms the correspondence between the effects of a training program and the characteristics of expert performance. It underlines the need to compare the impact of the training program with the specific performance of experts when developing sport-specific perceptual training programs.

In this context, particular emphasis should be placed on the improvements in the attention-oriented video groups. Highlighting versus not highlighting those body regions that indicate shot direction in the video material greatly reduces the depth prediction error. Orienting attention leads to a more rapid adaptation to the predictive skill of a badminton expert. It is suspected that orienting attention makes it possible to acquire the observation characteristics of a national league player.

Experts cannot improve their anticipatory skills from pretest to posttest through visual perception training. For this group it does not matter whether the video training is attention oriented or not. Through their many years of practical experience, national players possess amazingly good anticipatory skills that differ clearly from those of the other groups. We suspect that sport-specific perceptual skills approach a relative optimum asymptotically, making it increasingly hard to detect incremental improvements in skill at a very high expert level.

The main difference between national and local league players in estimating the direction of shuttles is that the national league players are much better at estimating the length (depth) compared with the direction (lateral). This result is obtained in the described prestudy (Hagemann & Strauss, 2006). It should be mentioned that the increase in radial prediction skill of the local league players in the training program is due almost exclusively to a better estimation of the length of shots. Here the video-based program precisely targets the weak point in local league players. It may well possess the potential to improve this specific perceptual deficit. However, this assumption needs to be confirmed through further training studies using control groups and transfer tests.

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Notes

[1]We also integrated 56 video clips of shots by different novice badminton players into the badminton test. The results from this experimental condition are not relevant for the present study and are not reported here (for more detail, see Hagemann & Strauss, 2006).

[2] This prestudy can be seen as an exploration study. Therefore, Hagemann and Strauss (2006) used an alpha level of .05 for each *t*-test, which gives the chance to detect middle size effects. However, using a Bonferroni-type alpha adjustment for the 7 *t*-tests at each temporal occlusion would result in an overall $\alpha = .0073$. Applying this α, a reliable reduction in the prediction of the landing position could be confirmed for the videos up to contact masking the racket ($p < .0001$, one-tailed, $d = .80$).

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